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THE FLIGHT OF BIRDS

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JOH. ALPH. BORELIUS.
De
MOTU
ANIMALIUM

LUGD. BATAV.
Apud DANIELEM A GAESBEECK.
CORNELIUM BOUTESTEYN.
JOANNIS DE VIVIE.
PETRUM VANDER AA.
1685.

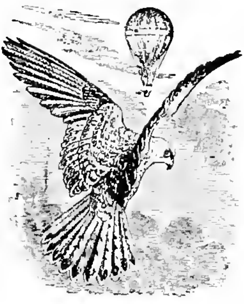
TITLE PAGE TO 2ND EDITION

Aeronautical Classics — **No. 6**

THE FLIGHT OF BIRDS

BY

GIOVANNI A. BORELLI



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EDITIONS OF "DE MOTU ANIMALIUM"

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of Great Britain
by
T. O'B. HUBBARD & J. H. LEDEBOER

BIOGRAPHICAL NOTICE

THE history of the 17th century is particularly remarkable for the rise of scientific learning which was the natural corollary to the revival of letters in the preceding hundred years. This period, in fact, bristles with erudite men, who with immense industry gathered up all the scientific lore of the ancient world, re-wrote it with voluminous commentaries and dissertations, and then boldly set out on the wide basis their labours had founded to build up all the branches of human science. Not the least among these was Giovanni Alphonso Borelli, son of Michael Alonzo and Laura, who was born at Naples on January 28, 1608. Of his early life very little is known, but at the age of forty he had already an established reputation in mathematics, anatomy, astronomy, and philosophy, and corresponded with many prominent members of the Royal Society of Great Britain; among others with Boyle, John Collins, Dr. Wallis, and the Secretary, Henry Oldenburgh. He held professorships at the Universities of Florence and of Pisa, and was in high favour with the princes of the house of Medici. About 1670 he lived for a short time at Messina, where he wrote a curious treatise—published in 1676—on the cause of the eruption of Mount Etna in 1669. During the revolt of Messina against the Spaniards in 1672 he was proclaimed a political suspect; therefore, returning to Italy, he settled near Rome, under the protection of Christine, the eccentric ex-Queen of Sweden, whose liberality considerably lightened the troubles of his later years. Shortly before he died he acted for two years as mathematical instructor in the convent of the regular clergy of St. Pantaleon, called the Pious Schools, where, it is related, he caused some flutter among the brethren which only his infirm age and reputation prevented from development into outcry, by attaching more importance to the pursuit of scientific knowledge than to the coming of the heavenly kingdom. His death occurred of pleurisy on December 31, 1679.

Of the long list of works that issued from his pen two only have carried his fame through the following centuries to modern times: "Theorice Medicæarum Planetarum," published at Florence, and the better-known posthumous "De Motu Animalium." The former deals with the movement of Jupiter's satellites, and exhibits an instinctive knowledge of gravitation without actually expressing it—a common characteristic of scientists of that day who "were wiser than they knew." The publication of "De Motu Animalium," the year after his death, put Borelli at once at the head of the Iatromathematical School, who sought to apply mathematics to the mechanics of living bodies. It raised a vast storm of discussion among the learned throughout Europe, a ferment that clarified into admiration.

The first part of this work deals with the mechanical action of the limbs of birds and animals, while his second considers a mechanical theory of the action of internal organs. The section called "De Volatu" in the first volume—which is translated in the following pages for the first time into English—is the only one that here concerns us. Da Vinci's earlier work on the subject of bird flight was then unknown—in fact, it lay undiscovered until the end of the 19th century—and "De Volatu" stands as an original study.

Substantially it is remarkably sound, and knowledge of it is an essential preliminary to any examination of the flight of birds. The Duke of Argyll* refers to the "admirable account" Borelli gives of the means by which birds are able to turn in the air and devotes a couple of pages to refuting his arguments on steerage in flight; Marey† writes "in the works of Borelli we find the first correct idea of the mechanism of flight. The wing, says this writer, acts on the air like a wedge. Developing still further the thought of the learned Neapolitan physiologist, we should now say that the wing of the bird acts on the air after the manner of the inclined plane. . . . . therefore we must be allowed to render to the genius of Borelli the justice which is due to him, and only claim for ourselves the merit of having furnished the experimental demonstration of a truth already suspected." Pettigrew ‡ explains Borelli's position at great length chiefly because "his doctrines have remained unquestioned for nearly two centuries and have been adopted by all the writers since his time, without, I regret to say, in the majority of cases, any acknowledgment whatever " and because "in commenting upon and differing from Borelli I will necessarily comment upon and differ from all his successors "; but he, too, gives him tribute when he states " it will not be too much to affirm that to this distinguished physiologist and mathematician belongs almost all the knowledge we possess of artificial wings up to 1865. He was well acquainted with the properties of the wedge, as applied to flight, and he was likewise cognisant of the flexible and elastic properties of the wing. To him is to be traced the purely mechanical theory of the wing's action."

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* "The Reign of Law," by the Duke of Argyll; London, 1866.

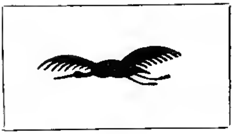
† "Animal Mechanism," ("La Machine animale," 1873), by J. Marey; London, 1874.

‡ "Aerial Locomotion," by J. B. Pettigrew; London, 1874.

To the verdict of these authorities there is nothing to add, save to draw attention to Borelli's overestimate of the power exerted by birds to maintain flight in his attempt to deduce it from the ratio between the weight of their muscles and their total weight. Borelli was human, and he made errors; but in the triumphant history of man's progress up to flight he has justly earned his place beside Leonardo da Vinci.

NOTE.—*The Editors, in preparing this volume, have endeavoured to make their translation as literal as possible; the chapters are given almost word for word, and there is no attempt at paraphrase to conform with modern expression. Their purpose has been to preserve, as far as possible, the flavour of the original.*

The section "De Volatu" is given in its entirety, save for Propositions CLXXXIV., CLXXXVI., CLXXXVII., *which have been omitted as they are of no general interest in the argument.*



THE FLIGHT OF BIRDS

As the beasts of the earth move on the land, so do the Birds wing their flight through the air. This motion of flight is accomplished with marvellous skill and by means of organic mechanism in such fashion as we shall here endeavour to set out.

¶ *The wing-structure and its component parts*

ALL biped and quadruped animals possess, in addition to their hind-legs, two arms, attached to the shoulder-blades, which are used by the quadruped for walking, by man for grasping, and by the Bird for flying. In all these various animals the arms are composed of the same number of joints, and the principal bones are similarly arranged: The shoulder-blade (*scapula*), the arm (*humerus*), the fore-arm (*cubitus* and *radius*), and the hand (*carpus*).

The shoulder-blades are rigidly joined to the extreme ends of the collar-bone (*clavicula*); which springs from the centre of the upper part of the breast-bone (*sternum*). But in Birds the shoulder-blade is of a different structure, most cunningly devised; it consists, namely, of the two long bones D L and D M, forming the acute angle L D M, of which the upper one L D adheres to the dorsal ribs, and is attached by several muscles to the spine.

The flat round extremity M of the lower scapular bone (*coracoid*) is most strongly attached by a tendon to the side of the breast-bone. In the angle N of the shoulder-blade adheres one end of the collar-bone K N, and in the angle D of the shoulder-blade there is a

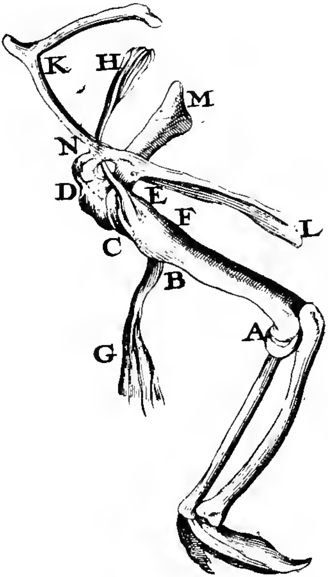


Fig. 1

round socket in which rotates the upper end of the arm-bone, attached there by a mighty tendon.

Furthermore in the hollow of the shoulder-blade there is a hole I*, through which runs, like a pulley, the tendon C I H of the muscle that raises the wing. Once more we may observe with admiration the value of Nature's foresight since the centre about which the wing rotates is most firmly placed on the twin fulcra of the bone D M, which forms the lower scapular bone, and of the collar-bone K N, these fulcra being supported by the crest of the breast-bone; and in this manner they are able to withstand the strongest movements of the pectoral muscle B G which depresses the wing. Two bones, forming the fore-arm (*cubitus* and *radius*), which are longer than the arm (*humerus*), are joined on to its extremity. To these again are attached the carpal bones, which in man are the hand, and in a Bird form the extreme portion of the wing. In length the carpus is slightly less than the arm.

The length of the wing-bones and of the feathers is not uniform in all Birds; that is to say, they have not the same proportion to the length of the Bird's body. For Ostriches have wings very short and slender in comparison to their huge bodies; Fowls and like Birds, which seldom, and then but for a short space, rise and fly, have somewhat larger wings; Pigeons larger still; but the greatest spread of wing is possessed by Eagles, Swans, Swallows, and those other Birds that are nearly always on the wing. In all these the wing-bones in length are equal to or greater than the length of the body of the Bird, measured from the end of the neck to the coccyx, and with their feathers added they are nearly thrice as long.

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* Shown, but not marked, in Fig. 1.—EDS.

The structure of the bones of a Bird also is admirable : for these consist of thin tubes of exceeding hardness, the walls whereof are much thinner than in the bones of men or quadrupeds. The reason for this is, as Galileo showed in masterly fashion in his new science of mechanics, that the weight of the bones is diminished but their strength and resistance increased by this tubular form, so that Birds might be adapted to fly well with light but strong wings.

With marvellous shrewdness, too, has Nature fashioned the feathers of the wings, so that they might strike the air with a strong beat, lightly, powerfully, and with the elasticity of a bow. Their substance is cartilaginous, yet hard as horn, with straight roots hollowed out to thin walls; these roots have curved prolongations that are filled with spongy marrow of exceeding lightness and is contained within a very hard, thin, convex skin, which is divided into two semicylinders, the convex side being placed over the concave side, so that after being curved both may be straightened out again by their elasticity, after the manner of a bow; so too, after being expanded they assume their curvature again, and thus strike the air with the greater force.

Most wonderfully, too, are shaped the hairy transverse feathery parts of the feathers which are of thin, most light, and yet strong structure, being elastic like a bow; and their hairy edges overlap so that they lie one over another, and thus hinder the passage of the air which they strike, like the sails of Ships. And, so that the penetration of the air may be even better prevented, other smaller feathers are disposed over the interstices, and down over them like the scales of Fishes; so that the whole wing surface is like the roof of a house composed of many tiles, and by the aid of all its parts prevents even the slightest rift.

¶ *The order and manner wherein Birds move their wings during flight.*

THAT we may lay bare the mechanical process whereby flight is effected, we must examine precisely the particular parts of the wings that are moved when Birds are in flight, and the order and particular mode of their motion. When Birds in repose rest on the earth, their wings are folded up close against their flanks: but when wishing to start on their flight, they first bend their legs and leap into the air. Whereupon the joints of their wings are straightened out, to form a straight line at right angles to the lateral surface of the breast, so that the two wings, outstretched, are placed as it were like the arms of a cross to the body of the Bird. Next, since the wings with their feathers attached form almost a plane surface, they are raised slightly above the horizontal, and with a most quick impulse beat down, in a direction almost perpendicular to the wing-plane, upon the underlying air; and to so intense a beat the air, notwithstanding it be fluid, offers resistance, partly by reason of its natural inertia which seeks to retain it at rest, and partly because the particles of the air, compressed by the swiftness of the stroke, resist this compression by their elasticity, just like the hard ground. Hence, the whole mass of the Bird rebounds, making a fresh leap through the air; whence it follows that flight is simply a motion composed of successive leaps accomplished through the air.

And I remark that a wing can easily beat the air in a direction almost perpendicular to its plane surface, although only a single one of the corners of the humerus bone is attached to the scapula, the whole extent of its base remaining free and loose, while the greater transverse feathers are joined to the lateral skin of the thorax. Nevertheless, the wing can easily revolve about its base like unto a fan.

Nor are there lacking tendon ligaments which restrain the feathers and prevent them from opening further, in the same fashion that sheets hold in the sails of Ships. No less admirable is Nature's cunning in unfolding and folding the wings upwards, for She folds them, not laterally, but by moving upwards edgewise the osseous parts wherein the roots of the feathers are inserted : for thus, without encountering the air's resistance, the upward motion of the wing-surface is made as with a sword; hence they can be uplifted with but small force. But thereafter, when the wings are twisted by being drawn transversely and by the resistance of the air, they are flattened as has been declared and will be made manifest hereafter.

¶ *A Bird's centre of gravity must be low.*

IT is known that the centre of gravity is the point in the centre of a body, wherefrom, if it be suspended, it will remain in equilibrium in every position; whereas, if it be suspended from any other point at a distance from the centre of gravity, then the body will not remain at rest save only in the single position wherein the straight line joining the point of suspension to the centre of gravity is perpendicular to the horizon. If there be taken the body A B C, which has its centre of gravity at D, and it be suspended from the point E, and it be possible to move it along the circumference of the circle F G D whose diameter F D is perpendicular to the horizon: it is indeed manifest that if the centre of gravity D be moved to any point G of the circumference of the circle, the body A B C, according to the law of the pendulum, will not remain at rest in that position, but will swing back to the lowest point D and remain there, for there alone is the line E D perpendicular to the horizon. Hence may be deduced conversely that, whenever the hanging body A B C, suspended from the

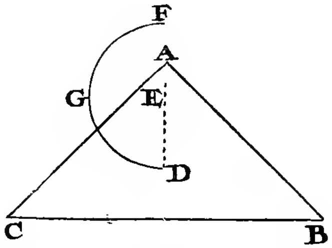

Fig. 2

point E, remains at rest and if after being swung returns to the same position so that the lower face B C is level, necessarily the centre of gravity must be some point in the vertical line E D situated below the point of suspension E.

Here be it also remarked that, if a body immersed in a fluid return ever to the same position, its centre of gravity must lie in the lower portion, nearest the earth. If, therefore, the ball A B, immersed in water or in the air, always return to the same position in which B is the lowest point, it must follow that the centre of gravity of the ball is situated in some point C, away from the centre, towards the point B, for this, too, follows from the law of the pendulum.

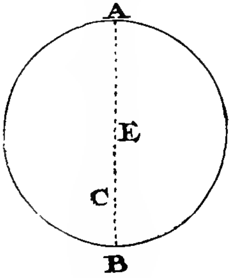

Fig. 3

Therefore, since we see a Bird in flight always with its belly level—a position that it maintains without any effort—it follows that its centre of gravity is situated in the lower part of the breast and belly.

Next, since a Bird—in itself heavier than the air—is sustained by the force of its wings and falls not, and since its body is suspended from the points of attachment of the wings in its upper part; therefore it is necessary that the centre of gravity should be below the roots of the wings in the lower part of the breast, and in a straight line perpendicular to the horizon and to the body of the Bird.

This statement is confirmed by the usual method whereby the centre of gravity of irregular bodies is ascertained. For if we place the body of a Bird plucked of its feathers, in various positions on the horizontal edge of a knife, we shall find that point where the Bird is balanced in equilibrium, that is the centre of gravity, in the straight line drawn from the articulations, or roots of the wings, to the middle-point of the pectoral bone, perpendicularly to the length of the Bird's body; in this precise position Birds rest when asleep on the twigs of trees.

We have seen already that the heavier parts of a Bird, which are the bigger, stronger bones and fleshy parts of the breast, are situated in the lower part of its body : for the bones of the legs and breast are large and strong. On the other hand, the backbone and ribs are thin and light. Similarly, the muscles of the breast, the thighs, and of the legs hanging below are equal or even superior in weight to the entrails and all the remaining muscles of the Bird together; so that the lower part of the breast should be by far the heavier, Nature placed the muscles that beat the wings, not in the upper shoulder-bone, but, as already noticed, in the middle of the pectoral muscle.

Opposed hereto, the upper thoracic cavity is filled with air, and is thereby lighter than the lower portion. The greater part of the abdominal cavity, also, is occupied by air above the intestines, which lie over the abdominal muscles by reason of their weight. From this disposition of the various parts we clearly perceive that Nature carefully devised that the centre of gravity of Birds should lie below the roots of the wings, so that they might remain on level belly in flight. For thus the heavy mechanism of the Bird may be sustained and prevented from falling by the powerful beating of the wings on the air.

Several observations may be brought forward against the above theory. For we may observe that in standing and in walking a Bird balances itself about a point situated between the joints of the shoulder-blades and the hips, through which passes a line drawn perpendicularly to the horizon and falling between the claws resting on the earth. Wherefrom it may be inferred that the centre of gravity of a Bird falls behind the joints of the wings, towards the tail. Moreover, when standing, a Bird holds not its body quite horizontally, but balances it in a slightly inclined position.

Though these things be true, yet are they not at variance with the theory above laid down; for, although the centre of gravity can never lie anywhere but in the position indicated, nevertheless this position itself may vary according to the requirements of the animal. The neck of a Bird, for instance, is of considerable heaviness by reason of the large number of bony vertebræ and the weight of the head : hence, if the head is either drawn back, or extended forwards, thus increasing horizontally the length of the body or diminishing it, the balance will be altered and the centre of gravity of the Bird will be displaced either towards the head, or towards the tail.

Thus, we may observe that a Goose when flying stretches forward its neck like the arm of a balance with the weight of the head at its extremity; wherefore the centre of gravity of the whole mass is displaced towards the head. Further, a Bird in flight always folds up the joints of its legs, drawing them up to the breast, save only in the case of Geese and some other Birds whose heads are heavy, so that the weight of the legs may be displaced either forwards or rearwards according to the requirements of equilibrium. Thirdly, when a Bird is on the ground, its wings are folded back against its flanks, thereby augmenting the weight in the rear: but when it flies, it spreads out its wings, bending them towards its head; thus making heavier its foremost part. By these three causes the centre of gravity of a Bird may be moved forward through a considerable distance, until the line joining it to the articulations of the wings be exactly perpendicular to the horizon and to the length of the Bird's body; thus, in a prone position, a Bird may most easily by beating the air with its wings fly through the air in successive leaps.

Most clearly, too, is this theory confirmed by the answer to the question, Why a Bird when sleeping hides its head beneath its wing. The first and obvious reason is that it cannot during its sleep perform a voluntary and fatiguing action, hence it cannot support the weight of its neck and head; wherefore it must perforce rest them somewhere. But the second reason that concerns the matter is that by drawing back its head and resting it on the rear part of its body, just as if it shortened the arm of a balance, the Bird moves rearward its centre of gravity so that the latter is placed vertically above the claws that firmly grasp the branch of the tree like a vice, as already stated; and thus the Bird may rest in equipoise. These observations have been set out first to give a clearer understanding of the mechanical work by which flight is effected.

¶ *The quantity of air acted upon by the wing of a Bird in flight is in shape a solid sector swept out by a radius equal to the span of the wing.*

LET there be a flying bird A C B G, the span of whose wing is equal to A I, and whose wing revolves when flapped about the centre A constituted by the joint of the humerus bone. Wherefore in its beat it moves through the sector A E P. But the wing A E is not simply a straight line, but a plane surface, and therefore in its motion it sweeps out a solid sector. In truth the wing strikes no air beyond that which is contained in the solid sector swept out by its motion.

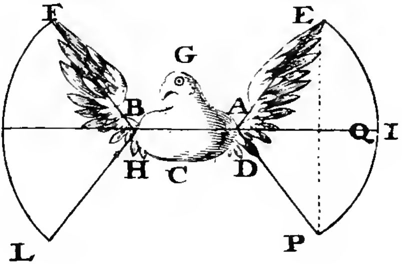

Fig. 4

¶ *Wherein is explained in what manner the air offers resistance to the stroke of the wings.*

THOUGH it be true indeed that the air may be set in motion and flow by any driving force, however weak, and hence appears to offer no resistance to motion; nevertheless experience teaches that it does resist the strong, swift beat of a wing, and with the greater force, the greater the swiftness of the beat. The causes of this resistance are evidently twofold. And firstly, since the air struck by the wing must of necessity be set in motion, whereas the surrounding air remains quiescent, as required by the nature of fluids; indeed, so that only a small portion of air be set in motion and displaced, it is necessary that it should be caused to rotate in a whirl within the great mass of quiescent air, as if in some enclosed vessel; and the particles of the round mass of air that is rotated will come into contact with and rub against the particles of the surrounding still air. But such friction and commotion cannot take place without the development of force and resistance; whence it follows that the stroke of the wing is opposed and resisted by the motion of the air.

Secondly, too, the air when struck offers resistance by its elastic virtue, through which the particles of the air compressed by the wing-beat strive to expand again. Through these two causes of resistance the downward beat of the wing is not only opposed, but even caused to recoil with a reflex movement; and these two causes of resistance ever increase the more the down-stroke of the wing is maintained and accelerated. On the other hand, the impulse of the wing is continuously diminished and weakened by the growing resistance. Hereby the force of the wing and the resistance become balanced; so that, manifestly, the air is beaten by the wing with the same force as the resistance to the stroke.

¶ *If the velocity wherewith the wings of a Bird in flight are beaten is equal to the velocity wherewith the underlying air recoils to the beat of the wing, the Bird remains in the same place.* (Fig. 4.)

If a Bird flying in the air beats its wing A E in the direction of P with the same velocity wherewith the air, struck by the wing, recoils in the same direction; then, I affirm, that the Bird A C B G will neither ascend nor fall. For the Bird would, if it were resting on the solid ground, rise from the ground to the extent that the wings E A, F B were beaten; but when the ground is not solid, but, being air, recoils with the same velocity wherewith it is struck, then the Bird will ascend through the beating of its wings in exactly the same measure as it is caused to fall by the recoil of the fluid air on which the wings rest; hence, relatively to the earth, it will remain at the same distance from the surface.

¶ *Again, if the velocity wherewith the wings are beaten is greater than the velocity wherewith the underlying air recoils to the beat, the Bird will ascend, and the rate of its ascent will be equal to the difference between the two velocities.*

In the same figure, since we suppose that the wing A E is beaten with greater velocity than the underlying air recoils to the beat, then the path described by the wing will be longer than that taken by the underlying air. But this is impossible, for the wing cannot be beaten in the air save by drawing along with itself the air that surrounds it. Hence the greater motion of the wing must be retarded and cut short by some mechanical device, in order that its motion may be the same as the shorter motion of the air. And this is effected most ingeniously by dragging upwards the centre A of the wing together with the Bird itself; whereby, although the tip E of the wing describes the greater path E P, nevertheless the actual path of travel, relatively to space, is diminished in the precise measure wherein the centre A of the wing, and with it the entire wing together with the Bird itself, is drawn back. Therefore the rate of ascent of the Bird is equal to the excess of the velocity of the wing-beat over the recoil of the air beneath.

¶ *The power of those muscles that beat the wings is greater by ten-thousand times than the weight of the Bird.*

ALREADY we have showed that the power required for a man to leap is almost three-thousand times greater than his own weight; but with Birds it can be demonstrated that the power necessary for making a leap is in greater proportion still to their weight. For their weight is triply suspended in like manner and the leverage of their longer legs increases in much greater measure than in the case of men the motive force, which again is multiplied more than twenty times by the number of the muscles of the legs; and lastly the motive force will be increased by the violence and swiftness of the leap, so that it is greater by three-thousand times than the weight of the Bird which leaps.

These things being so, since flight is effected by successive leaps through the leverage of the wings, which are strongly flapped by the two pectoral muscles; and since the motive power exerted by muscles is for any animal, as has been shown, proportional to the size of the muscles; therefore, the number and length of the ligaments, no less than the fleshy bulk of the muscles that beat the wings being greater, stronger, and not less in extent than the flesh of all the muscles of the legs, it is manifest that the power employed by Nature to beat the wings is greater than that put forth in leaping from the ground. Next, I observe that the bulk and weight of the muscles of a man's legs are less in proportion to the bulk and weight of his entire body than is the case with a Bird; but the power of all muscles has always the same proportion to the resistance of the body they support, as the bulk or weight. Wherefore the power of the muscles in a man's legs only exceeds the weight of his body to a far smaller extent than the power of the wings of a Bird surpasses the weight of its body.

Moreover, I notice that the leaps through the air which are made during flight may be continued during four hours and more without intermission; nay, we may see Swallows on the wing throughout the day; but on the ground neither men nor four-footed beasts, no, nor

Birds with clipped wings, can continue to leap with the same vehemence for the space of half-an-hour or an hour. And muscular power, the longer it acts and remains capable of raising many times the same weight. must by so much be more abundant and efficient, as in the case where it is not able to perform the same task, or only for a shorter time. Therefore the power of the wing-muscles is greater far than the power of the leg-muscles; it is, in fact, more than four times as great. And this may be proved by this argument. If a man stand first on hard and firm ground, and next on a mattress of wool or sand, or any yielding surface; and if, bending his legs, he leaps with the same strength in each case, it is evident that the leap made from the hard ground will be the greater, while that made from soft and yielding ground will be the smaller. If, however, the leaps are to be equal in each case, that is to say if they are to reach to the same height, it is necessary that the man standing on yielding ground exert greater strength than the other one in the exact measure that the motion of recoil is diminished by the softness of the ground, for the recoil is the cause of the leap. And since the air, on which the wings of Birds are supported, is fluid and yielding, for this reason the action of flying, or of making leaps through the air, requires far greater power; in fact, four times as much as is required for a leap from the firm gound. But this power has been shown to be almost three-thousand times greater than the weight of the animal to be lifted. Hence the power that is exerted by the pectoral muscles during flight can be not less than ten-thousand times the weight of the bird.

¶ *Wherein are set forth the reasons for the immense power of the wings.*

SUCH excessive power of the pectoral muscles of Birds seems to arise, firstly, from their large size and from the more compact and stronger organic structure of the fibres of the pectoral muscles; for these fibres are thicker and closer, forming a dense and compact fleshy structure, whereas the muscles of the legs are formed of meagre, spare flesh. By reason hereof the former can be extended more forcefully and vehemently, so that the former are able to exert more power than the latter.

Secondly, the action of the wings is increased by the decrease in resistance, for the body of a Bird is disproportionately lighter than that of man or of any quadruped; that is, the weight of a Bird is in smaller proportion to the weight of the latter animals than its mass to theirs. This is evident since the bones of a Bird are porous, hollowed out to extreme thinness like the roots of the feathers, and the shoulder-bones, ribs, and wing-bones are of little substance; the breast and abdomen contain large cavities filled with air; while the feathers and the down are of exceeding lightness. Hence the power of the wings is increased in duplicate ratio : firstly, by the increase in the force of the muscles, and secondly by the decrease of the weight to be supported.

This downward pull is diminished the more as its downward movement is retarded by the spread of the wings and of the tail; hence the force of the wings can the more readily effect the leaps through the air, as the resistance of the downward pull of the Bird itself is diminished.

Thirdly, in leaping from the earth the projectile momentum is immediately extinguished so soon as the feet come into contact with the earth again; whence it follows that the momentum must forthwith be renewed. On the contrary, when a Bird is flying through the air, the projectile force is not extinguished by the fluid air, wherefore it assists the succeeding leaps which are made by the beating of the wings.

Fourthly, in effecting separate leaps from the earth, the soles of the feet come into contact with the ground not without experiencing hurt and painful injury, whence arise fatigue and weakness. But no such hurt results from leaping through the air; wherefore, since the motive force is not weakened to the same extent, longer, more powerful, and more lasting leaps may be made through the air. The various causes set forth above render the process abundantly clear.

¶ *In what manner an oblique transverse force may propel straightly a body unaffected by the motion.*

IT is taught by the science of mechanics that the action of the wedge A B C, through which two parts E F G and L M N of the same body must be separated from one another, amounts to the forcing of the two resisting bodies D E and H M over the inclined surfaces C A and C B of the wedge, along which they seek to ascend when the wedge is driven in a direction from I to C. And the same transverse motion over the inclined faces C A and C B must take place when the two adjacent bodies

D F and H M are forced towards each other; for in this case the smooth wedge A B C seeks to escape in the opposite direction and to recoil from C to I, being expelled through the pressure of the collateral bodies, in the same manner as the smooth pips of a fruit may be projected to a long distance by being compressed between one's fingers. And this propulsion is made with the same force and momentum as that wherewith the bodies D F and H M compress the inclined faces C A and C B: the expelling force having the same proportion to their absolute force as the heights A I, B I of the planes to the lengths A C, B C of their inclination.

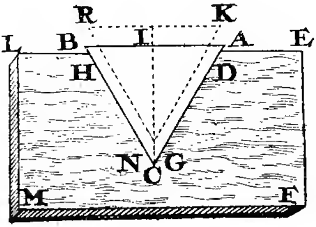

Fig. 5

¶ *If a Bird suspended in the air strike with its outspread wings the undisturbed air, with a motion perpendicular to the horizon, it will fly with a transverse movement parallel to the horizon.*

LET the Bird R S be suspended in the air with its wings B E A and B C F expanded and its belly downwards, and the under surfaces of the wings B E A and B C F strike against the wind perpendicularly to the horizon with such force as to prevent the bird from falling, then I hold that it will be impelled horizontally from S towards R. And this happens because the two osseous rods (*virgae*) B C and B E by muscular strength and on account of their hardness are able to resist the pressure of the wind, and, moreover, to retain their shape, but the afterparts of any kind of wing yield to the air pressure, as the flexible feathers are able to move about the wing bones (*manubria*) or their boney axes B C and B E; and so it follows that the ends A

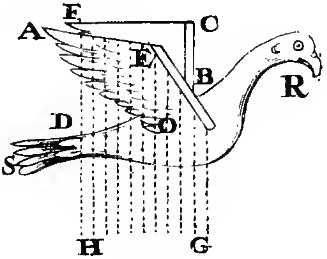

Fig. 6

and F of the feathers close in towards one another, by which means the wings assume the form of a wedge with its apex towards A F. But as the surfaces of the wedge are compressed on all sides by the ascending air, the wedge is of necessity squeezed and driven towards its base C B E. And as the said wedge formed by the wings cannot move forward without taking with it, since it is attached thereto, the body of the Bird R S, which is swimming in the air and can therefore be moved freely from its position, for this reason it is able to give room to the incoming air in the place of the air driven out; and therefore the bird moves with a horizontal motion towards R.*

Let us now take the case of undisturbed opposing air which is struck by the flexible portions of the wings with a movement perpendicular to the horizon. Since the sails and flexible portions of the wings assume the shape of a wedge, with the apex towards the tail, when acted upon by the force and compression of the air, whether the wings strike the quiescent air beneath, or whether the air rushes up against the outstretched wings with their rigid wing-bones; in both cases the flexible feathers of each wing yield to the pressure and close in towards one another. Therefore, of necessity, as will be presently shown, the bird will be moved forwards towards R.

¶ *Wherein is explained the way in which the horizontal flight of Birds is effected.*

To have brought about flight, it is evident that Nature impelled birds upward and held them suspended in the air, and afterwards they were enabled by horizontal movements to be carried about. The first step could not have been accomplished except by successive leaps; next the heavy bird was carried up and its descent prevented by the beating of its wings, and then, as the downward pull of its weight is perpendicular to the horizon, beats with the flat face of its wings would be made by striking the air in the same perpendicular direction; and in this fashion has Nature brought about the suspension of the Birds in the air.

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* A somewhat obscure passage. The argument is re-stated in more explicit terms in the next paragraph.—EDS.

Concerning the second and transverse motion of Birds, some people do blunder strangely, for they think that it ought to be done as in Ships, which, by the exertion of a horizontal force towards the stern, through the means of oars, the while floating on the quiet and therefore resisting water beneath, recoil at the contrary motion, and so are moved forward. In the same way they affirm that the wings are flapped with a horizontal movement towards the tail and so strike against the undisturbed air, the resistance of which occasions, by the reflex action, their forward motion.

But this is repellent to the evidence of the senses and of reason, for we never see the larger Birds, such as Swans, Geese, and the like, while flying, to flap their wings towards the tail with a horizontal motion, but always to incline them downwards, describing circles set perpendicularly to the horizon. Moreover, in Ships, the horizontal motion of the oars can be easily accomplished and a perpendicular stroke upon the water would be useless and unnecessary, as there is no need to prevent their descent when they are sustained by the weight and density of the water. But in the case of Birds, it would be foolish to make such a horizontal motion, which would rather hinder flight as the speedy downfall of the heavy Bird would result from it; wherefore, the Bird must be sustained by continual vibrations of the wings perpendicularly to the horizon.

Wherefore Nature was compelled to use, with remarkable shrewdness, a movement which both sustained the Bird and propelled it horizontally. It accomplishes this by beating the air perpendicularly to the horizon, but with oblique strokes, which is rendered possible solely by the flexibility of the feathers; for in the act of striking the wing-fans acquire the shape of a wedge, so that of necessity the Bird is moved forward horizontally, as has been said.

¶ *The use of the tail of the Bird is to direct the course of flight upwards and downwards; but not to the right and left.*

THE opinion derived from the ancient Philosophers prevails that the tail in Birds performs the same function as the rudder in Ships; and because Ships, floating horizontally on the smooth surface of the water, can be turned by the effect of the helm only to the right and left, hence it is commonly believed that Birds direct their bodies to the right and left, when flying, by the movement of the tail.

Of a truth the falsity of this opinion can be easily proved not only by reason but by experience. Because, if the rudder of a Ship were adapted in the same way and placed in the same position as the tail in a Bird, that is to say, if the face of the rudder-blade with the changed axis were fixed to the stern, not perpendicularly to the horizon and to the surface of the water, but extended horizontally, so that in the water it could be inclined upwards and downwards to the surface thereof, then indeed were one able to see that the Ship could in no wise be turned to the right nor to the left by such alteration of its rudder.

Moreover, we see that Pigeons, Swallows, and

Hawks, when they direct their course horizontally to the right or to the left, do not spread their tail, nor do they bend it up nor yet down, but hold it straight. Finally, Pigeons with their tails cut, or Bats that possess no tails at all, easily turn in the air and make horizontal curves in their flight. And these examples must in sufficient measure confute the common error.

But I will not deny that the tail in Birds truly may perform the use and function of a rudder; but I affirm that it serves to direct the course in flight upwards and downwards. And this I prove as follows:

Let there be a Bird A B with its centre of gravity at C; now this Bird while flying directly and horizontally from G to F inclines downwards the surface of its long tail B H. For, while the Bird moves from G to F, through quiet and still air, its body surface A B is able to glide forwards freely and without impediment. Not so its rear part, the upheld surface of which is not straight and level, on account of the elevation of the big and very long tail B H, which strikes against the still air; and by this means such striking of the air tends to remove the aforesaid obstacle, as it would stretch the tail out straight if it were not held in its curved position by muscular force. Wherefore it fol-

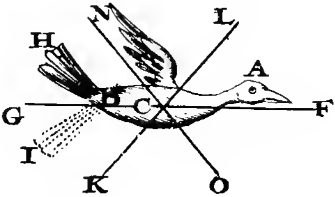

Fig. 7

lows that, as the whole body of the Bird is turned about its centre of gravity C on which it is poised, it must assume the position L K, and its head must be moved up from A to L.

In the same way, if the tail be depressed as in B I, when the Bird is flying from G towards F, it strikes the quiet air beneath, and in this way the tail is raised from B towards N around the same centre of gravity C and therefore the head A is lowered towards O. A mechanical demonstration proves this, which can also be confirmed by experiment.

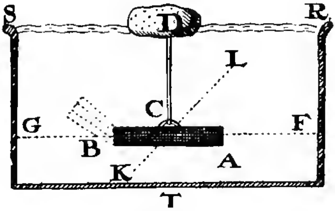

Fig. 8

In the vessel R S T, full of water, an oblong strip of iron A B is sunk, which is suspended from its centre of gravity C by a thread tied to the cork D, so that the immersed strip can be moved horizontally, and a small strip B H is attached to its rear edge like a Bird's tail. If this small strip be bent upwards and the body A B be drawn by the thread C D horizontally towards F, the leading end A is turned by the swift motion towards L about its centre of gravity C, nor does it ever revolve horizontally to the right or to the left; wherefore this should also hold good of Birds flying through the air.

¶ *How and by what means Birds, when flying, alter their course to the right or to the left.*

EXPERIENCE and reason show that a small rudder moved to the left may slowly turn a big Ship in the same direction when the Ship is travelling on a straight course through the water; but while the Ship is at rest, that is to say, if it is not propelled by the wind or by oars, then the rudder will effect no turn at all in the Ship's course. In the other case, where there is no rudder, if the oars on the right side are pulled so as to drive the water towards the stern, whether the Ship be still or whether under way, the bows are always speedily turned towards the left side.

This also happens, if the oars on the right side drive the water backwards more swiftly than those on the left. The reason for this does not warrant explanation, since it is self-evident; therefore, in the same way, while a Bird is floating in the air, poised on its centre of gravity, if the right wing alone is bent obliquely downwards, driving the air towards its tail, its right side of necessity—as in a Ship, as will be seen—will be moved gently and slowly to the left side. From which it follows that the fore part of the Bird, moving round its centre of gravity, is turned towards the left side.

We ourselves in truth experience this, while swimming; for by bending the right arm, with the hand stretched towards the rear, we turn horizontally to the left. We have observed this in Pigeons flying; for whenever they wish to turn towards the left side they raise their right wing and flap it strongly, driving the air with an oblique motion towards the tail; from which it follows that the shoulder and whole right side of the Bird are raised above the horizontal plane, whereas the left side is depressed because the Bird's weight is not equally sustained by the uneven flapping. By this means the turn and deviation of a Bird moving horizontally are very quickly made. Finally, I am of opinion that the turn cannot be effected by a lateral movement of the Bird's tail in the same way as a rudder, because the tail can never be set perpendicularly to the horizon, but only obliquely.

And such obliqueness goes for nothing if the tail feathers are spread in the same direction as the rest of the body or from its axis like a waving flag; but it is necessary that the tail be bent both away from the direction of the Bird's axis and from its direction of motion in the horizontal plane. In this way, at best, the tail can only be obliquely inclined between the vertical and the horizontal. And because we see in Pigeons flying that such inclination of the tail feathers from the horizontal is very small, therefore they should go up or down more often than to one side; but this is not borne out by experience, for we see that in the same horizontal plane Birds turn with great quickness.

I do affirm, therefore, that birds do not spread the tail when turning sideways, but when going up or down, and most of all when they are slackening the speed they have gathered, so as to land without shock or hurt.

At the same time the argument is advanced that it can be sufficiently well done (*i.e.*, the turn with tail), though with difficulty.

¶ *If the body of the Bird A C be moved at an acquired speed through the air in a longitudinal direction from C towards A, and if while flying it bend its outstretched neck with its head B A towards the left side B I, the course of the entire Bird is deflected towards B I.*

LET D be the centre of gravity of the body of the bird B C, and let E be the centre of gravity of the head and long neck A B, and when the neck is bent to B I let the centre of gravity be at F; join D F.

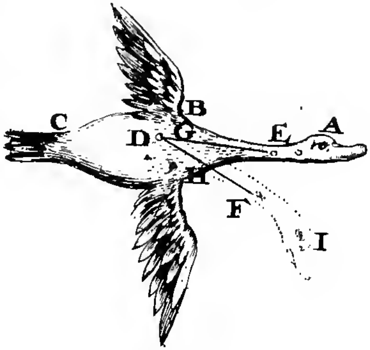

Fig. 9

Now as the weight C B is to B A, or to B I, so is the distance E G to G D; therefore F H is equal to H D.

It is plain that before the neck is bent the centre of gravity of the whole Bird will be in G, and that from the acquired speed it would be carried from D towards E. But as the neck is bent, the same centre of gravity G is turned from this direct course and it moves from G towards H, but retains the same initial impetus from the tail towards the head. Therefore from these two forces a transverse motion is set up in the direction D I, which course is subsequently followed by the Bird.

¶ *It does not appear possible that Birds, flying horizontally, can depart quickly from their course by the transverse flexion of their head and neck.*

LET us consider the two ways by which a Ship, moving through the water, is able to turn to the right and to the left. Firstly, if the oars on one side impel the water more strongly towards the stern than the oars on the other side. Secondly, if, while the ship is moving, the rudder, either in the stern or in the prow, is turned laterally, perpendicularly to the horizon. These two operations largely differ from one another; for the turning of the Ship is effected, on the one hand, by a considerable exertion of motive force on the part of the rowers, and on the other by the inappreciable power of the Steersman grasping the tiller, who, though directing the movement, does not effect it by his own strength, but from the impetus acquired by the Ship and from the rudder resisting the impact of the water; moreover, the turning movement made by the oars on one side is performed very quickly, but very slowly by the rudder.

From these facts we can judge, in the similar action of Birds flying, whether the bending of the neck can not fulfil the function of a rudder.

Firstly, if the neck inclined laterally had the strength of a rudder and thereby the Bird were able to alter its course to the right and left, therefore, in the same way, by raising or lowering its neck, a Bird in flight were able to direct its course upwards or downwards.

But, as it cannot be said that the large tail, which, acting as a rudder, so evidently produces the up and down movements, was made by Nature for no reason, it must be confessed that the bending of the neck does not fulfil the function of a rudder.

Secondly, Eagles, Hawks, and Swallows have a very short neck and a small head of but little weight; therefore, the centre of gravity could only deviate a very small way from the direction of the axis of the Bird and for this reason it would only turn with much difficulty and very slowly in a lateral direction; but so false is this, that in truth they whirl round almost in the twinkling of an eye; while, on the other hand, Geese, Ducks, and Swans and other Birds of this kind, possessed of a long neck and a very heavy head and beak, turn most slowly when they are flying. It must therefore be confessed that bending the head and neck laterally in no wise produces a horizontal turning movement.

Thirdly, if the centre of gravity of the entire Bird should depart considerably from its axis by a lateral bending of the neck, the Bird could not maintain its horizontal equilibrium, and therefore the side depressed would have to be righted by a violent exertion of the wing on that side. From which it would follow that a contrary action to the first would be made in the interests of gravity, which would interfere with the turning movement; and such an action would be vain and useless; moreover being foolish and sorely at variance with Nature's shrewdness.

Nor may you say that the speediest turns of Birds are made by the strong flapping of one wing towards the tail, and that slow turns can be made by bending the neck sideways without any special effort by the wing, in the same way as Ships are put about by means of a rudder and without using the oars, for I am of opinion that the slow circling of a bird is accomplished not by a stronger movement of one wing that either of them exert in straight flight; for it is sufficient that the wing, to make the turn, should incline for a little while towards the tail and strike the air there, so that without any fresh exertion the slow lateral turn of the bird may be accomplished in the quickest way.

¶ *How Birds, without flapping their wings, can sometimes rise in the air for a short time not only horizontally, but also obliquely upward.*

IT is clear from what has been said that the projectile force is communicated to a Bird's body by the flapping of the wings in the same way as motion is given to a Ship by the strokes of the oars, which motion is of a constant nature.

Suppose, however, that the action of the oars stops, nevertheless the Ship proceeds upon its way until its movement is arrested by external forces.

Therefore both Bird and Ship from the motion imparted to them have the same properties as an arrow and other projectiles; and just as in a Ship in motion, if its axis is deflected from a straight course by the strength of the helm, then this same motion comes into play on the altered course, and the voyage is continued; so also in the Bird A, moving horizontally along the straight line A B C, as often as its axis is directed upward through B D by the force of its tail acting as a helm, of necessity its impetus follows an upward movement through the parabolical curve B E F, but it is true that such ascent stops suddenly, the natural gravity of a Bird producing this effect and tending to bring it down. While the force of gravity is less than the velocity, the Bird rises upwards through B E, and when at F the forces equalise, the Bird is seen to float at that point for a little while, moving with expanded wings,

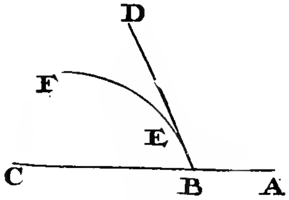

Fig. 10

almost in the same plane parallel to the horizon; for a bird cannot remain entirely motionless at the same point in the air, therefore upward flight cannot be made exactly perpendicularly to the horizon, but always obliquely through the line of a parabola, as projectiles move.

Therefore, after this rise is made, either the bird continues in a horizontal course for a short time because the equalisation of the forces soon ceases, or as the projectile force is spent it descends at a constantly increasing speed until brought up by external forces. Hence the necessity arises for renewing the impulse through the air by fresh strokes of the wings.

I note also that the two forces aforesaid, projectile and natural gravity, sometimes mutually retard and destroy each other, as happens in ascent; and sometimes add to one another so that a very high velocity results from their combination, thus Hawks fall down like arrows to strike little Birds and tear them with their claws.

There are, indeed, some who imagine that Birds hover in the high regions of the air with less difficulty than when near the earth, because they think they weigh less there on account of being less attracted by the earth's magnetic force, which is the cause of gravity according to their ideas; for just as iron when far away from a magnet does not feel its power nor is attracted by it, so they think Birds when high up escape from the force of gravity. And they imagine that this is why Eagles, flying high, are seen, as it were, at rest in the air with their wings spread and motionless for long periods, whilst near the earth when beginning to fly they are compelled to beat the air with quick recurring strokes.

But such ideas appear invalid. Firstly, on account of the difficulty of the hypothesis, as we explain elsewhere; secondly, because Hawks, when near the ground where the magnetic force is supposed to have the greatest effect, after they have acquired an impetus, do not flap continually, but with the same infrequence as when high up, and nevertheless they fly quite easily. Therefore they are able to hover without continual flaps in the highest aerial regions, not on account of the decreased magnetic virtue of the earth, but by strength and acquired momentum.

Thirdly, the high regions of the air are never quite still, but are always agitated by the wind as the movements of the clouds show; so the Bird with outspread wings is carried up by the wind, or at any rate the spread wings allow it to come down very slowly. In the air, the descending force of gravity is retarded by the wide surface opposed, in the same way as a strip of very thin iron sinks very slowly through water if care is taken that it does not fall edgewise. Hence it is inferred what the most potent causes of the easy flying of a Bird, in the high air, can be.

¶ *How the flying impetus acquired by a Bird is checked on landing.*

BECAUSE of the law of Nature that hard bodies in motion cannot come into contact with another hard and stationary body without a shock which causes their parts to break and shiver; it is necessary to insure that Birds at the end of a flight should come to ground without dislocating or breaking their legs, wherefore the severe shock, which bodies in motion incur, must be avoided.

But this cannot be done unless the Bird's impetus is gradually checked and stopped before it comes in contact with the earth, for, when impetus is lost, a gentle landing can be made.

Now the ways and means by which the speed is slackened at the end of a flight are these. The Bird spreads its wings and tail so that their concave surfaces are perpendicular to the direction of motion; in this way, the spreading feathers, like a Ship's sails, strike against the still air, check the speed, and so that most of the impetus may be stopped, the wings are flapped quickly and strongly forward, inducing a contrary motion so that the bird absolutely or very nearly stops.

Any remaining impetus is absorbed by its extended feet, so that it takes the ground not heavily, but gradually, with bent joints yielding to the impact and with slowly relaxing muscles.

¶ *It is impossible that men should be able to fly craftily by their own strength.*

THREE principal points ought to be considered in flying: firstly, the motive power by which the body of the Animal may be sustained through the air; secondly, the suitable instruments, which are wings; thirdly, the resistance of the Animal's heavy body.

The degree of motive power is known by the strength and quantity of the muscles, which are designed to bend the arms or to flap the wings. And because the motive force in Birds' wings is apparently ten-thousand times greater than the resistance of their weight, and as Nature has endowed Birds with so great an excess of motive power, the Bird largely increases the strength of its pectoral muscles and skilfully decreases the weight of its body, as we have hinted above.

When, therefore, it is asked whether men may be able to fly by their own strength, it must be seen whether the motive power of the pectoral muscles (the strength of which is indicated and measured by their size), is proportionately great, as it is evident that it must exceed the resistance of the weight of the whole human body ten-thousand times, together with the weight of enormous wings which should be attached to the arms. And it is clear that the motive power of the pectoral muscles in men is much less than is necessary for flight, for in Birds the bulk and weight of the muscles for flapping the wings are not less than a sixth part of the entire weight of the body. Therefore, it would be necessary that the pectoral muscles of a man should weigh more than a sixth part of the entire weight of his body; so also the arms, by flapping with the wings attached, should be able to exert a power ten-thousand times greater than the weight of the human body itself. But they are far below such excess, for the aforesaid pectoral muscles do not equal a hundredth part of the entire weight of a man. Wherefore either the strength of the muscles ought to be increased or the weight of the human body must be decreased, so that the same proportion obtains in it as exists in Birds.

Hence it is deduced, that the Icarian invention is entirely mythical because impossible; for it is not possible either to increase a man's pectoral muscles or to diminish the weight of the human body; and whatever apparatus is used, although it is possible to increase the momentum, the velocity or the power employed can never equal the resistance; and therefore wing flapping by the contraction of muscles cannot give out enough power to carry up the heavy body of a man.

There only remains the diminution of the weight of the human body, not in itself, for this is impossible, its mechanism must remain intact, but especially and respectively to the aerial fluid in the same way as a strip of lead can float on water if a certain amount of cork be attached to it which causes the entire mass of lead and cork to float, being of like weight to the amount of water which it displaces, according to the law of Archimedes. And this device Nature uses in fishes. She places in their bellies a sack full of air by means of which they are able to maintain their equilibrium, so that they can remain in the same place as if they were part of the water itself.

By this same device some have lately persuaded themselves that the weight of the human body is able to be brought into equilibrium with the air, that is to say by the use of a large vessel, either a vacuum or very nearly so, of so great a size that it is possible to sustain a human body in the air together with the vessel.*

But we easily perceive this to be a vain hope as it is necessary to construct the vessel of some hard metal such as brass or copper, and squeeze out and take away all the air from its interior, and it must also be of so great a size that when in the air it displaces a quantity of air of the same weight as itself, together with the man fastened to it; wherefore it would have to occupy a space of more than 22,000 cubic feet; moreover, the plates composing the sphere must be reduced to an extraordinary thinness. Furthermore, so thin a vessel of this size could not be constructed, or, if constructed, preserved intact, nor could it be exhausted by any pump, much less by mercury, of which so large a quantity is not to be found in the world, nor could be extracted from the earth, and if such a great vacuum were made the thin brass vessel could not resist the strong pressure of the air, which would break or crush it. I pass over the fact that so great a machine of the same weight as the air would not be able to keep itself in exact equilibrium with the air, and therefore would incontinently rise to the highest confines of the air like clouds, or would fall to the ground.

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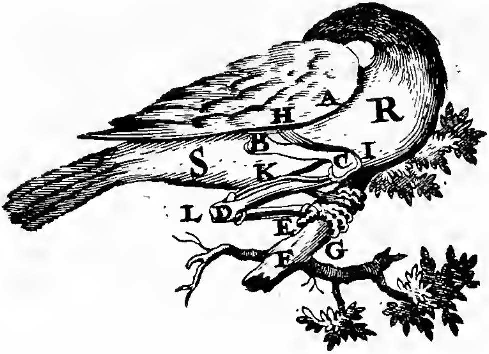
* The reference is to the writings of Francesco Lana and his imitators, Sturm and others.—*Vide* "Aeronautical Classics," No. 4.—EDS.

Again, such a large mass could not be moved in flight on account of the resistance of the air; in the same way feathers and soap bubbles can be moved only with difficulty through the air, even when they are blown by a light breeze, just as clouds, poised in the air, are driven by the wind.

At this point we cease to wonder that Nature, who is accustomed everywhere to imitate others' advantages, makes the swimming of fishes in water so easy and the flying of Birds through the air so difficult, for we see whereas fishes can remain in the midst of water, being of their own accord and without effort held up and poised, and can very easily descend and ascend, and are only moved by the strength of muscles placed transversely and obliquely to the direction of motion; on the other hand, Birds are not able to float in the air but owe their sustentation to the continual exertion of strength and a projectile force, not external, but natural and intrinsic, by contracting their pectoral muscles by which they make a series of bounds through the air; and this requires enormous strength, as they are not going upon feet supported on solid ground, but on wings supported by very fluid and greatly agitated air.

Nevertheless, I say that the act of flying is not difficult; indeed it is very simple and very easy in the various possible ways by which it can be accomplished. And the reason why flying is not performed in the same way as swimming is that Nature does not work miracles; fishes can easily float in heavy water, but it is impossible that Birds, made of bones, flesh, and blood two-thousand times heavier than the air, can float in the air.



See page 9.

I.—OBJECTS OF THE AËRONAUTICAL SOCIETY

The Society (established 1866) was the first ever formed in any country, and is now in the 45th year of its existence. Its objects are:—

(*a*) To give a stronger impulse to the scientific study of aerial navigation in all its branches.

(*b*) To promote the intercourse of those interested in the subject at home and abroad.

(*c*) To aid, with advice and instruction, those studying the principles upon which Aeronautical Science is based.

From its foundation, the Society has made a special study of dynamic flight, giving it the priority over ballooning.

II.—THE WORK OF THE SOCIETY

In order to carry out the objects for which the Society exists, the following arrangements are made:—

(*a*) **Meetings** of the Members are held at which papers on aeronautical subjects are read and discussed.

These meetings are usually held quarterly, and have, except for a short period, been carried on ever since the Society was first established. The papers are read by Members and other persons interested in aeronautical science, and the discussions which follow them are often of great interest. All Members can attend these meetings and introduce two visitors.

Minor Meetings of an informal nature are also held at the Society's Offices.

(*b*) **A Quarterly Journal** is published and issued to members free of charge. The original "Reports of the Aëronautical Society of Great Britain" (23 in number) were issued annually, and are of considerable value, as they contain a great deal of useful information on aeronautical subjects, and may almost be said to form the basis of modern aeronautical science.

In 1897 the *Aëronautical Journal* was substituted for the Reports (the issue of which had lapsed), as it was considered that a quarterly issue would more effectually carry out the objects for which the Society exists. This Journal contains full reports of the Society's meetings, and is well illustrated. A great deal of miscellaneous aeronautical information is also given in it, a special feature being reviews of current aeronautical literature.

(*c*) **A Library** is maintained. This library contains nearly all the well-known aeronautical works, some of them being of great value, and all modern books and publications can be borrowed by members. It is well supplied with the journals, magazines, etc., of other societies and clubs, both at home and abroad, and is a very beneficial institution to those who desire to gain a true knowledge of aeronautical science.

Books, lantern slides, and models for lecture purposes are issued on loan to Members only.

(*d*) **Advice and Information** on aeronautical subjects. Members requiring information on particular points are placed in communication with other Members specially qualified to give the required information. A great deal of general information is available to Members on enquiry at the Society's Offices.

Members travelling abroad are furnished with introductions to foreign aeronautical societies, and are thus brought in touch with foreign aeronautical lines of development.

It may be mentioned here that the Society is well represented on the *only two international scientific societies*, viz., "The International Commission for Scientific Aeronautics" and "The Permanent International Aeronautical Committee."

(*e*) **An Experimental Laboratory** is in process of formation, from which it is hoped to obtain exceedingly valuable data.

(*f*) **Medals** are awarded by the Society for distinguished services to aeronautics, particularly for scientific research and experiment.

A Bronze Medal is also awarded annually to the author of the best paper appearing in the *Aëronautical Journal* during the year.

Gold Medallists.—Wilbur and Orville Wright (1909).
Octave Chanute (1910).
Silver Medallist.—Samuel F. Cody (1909).
Bronze Medallists.—W. R. Turnbull (1908).
F. W. Lanchester (1909).
B. G. Cooper (1910).

(*g*) **Reports** by the Committees are published periodically. Reprints of valuable contributions to the science are occasionally issued. The following have already appeared:—

1897. "The Navigation of the Air," by Alex. McCallum. (Reprinted from the *Glasgow Herald.*)

1910-11. "Aeronautical Classics." 6 vols. (including the writings of Sir George Cayley, F. H. Wenham, T. Walker, F. J. Stringfellow, P. S. Pilcher, Borelli, which are being published at intervals).

III.—SUBSCRIPTIONS, ETC.

1. The Entrance Fee is £1 1s., which should be forwarded with the application for membership, and is returnable in the event of non-election.

2. The Annual Subscription to the Society is £1 1s., payable on January 1st each year. Members joining after October 1st in any year do not pay subscriptions for the following year.

IV.—MEMBERSHIP

Members' names come up for election at the first Council Meeting held after the receipt of their membership application forms.

Anyone desirous of becoming a member should apply to the Secretary, from whom all particulars may be obtained.

V.—PRESIDENTS OF THE AËRONAUTICAL SOCIETY OF GREAT BRITAIN

1866-1896. His Grace The Duke of Argyll.
1897-1900. [No President appointed.]
1901-1907. Major B. Baden-Powell (*Scots Guards*).
1908-1911. E. P. Frost, D.L., J.P.

Gaylord
PAMPHLET BINDER
Syracuse, N. Y.
Stockton, Calif.